Complications of Interventional Treatment of Cerebral Aneurysms

R. SELLAR

Western General Hospital; Edinburgh, Scotland, Uk

Key words: cerebral aneurysms, coiling, complications, rupture, thrombo-embolism, coil migration, stenting, balloon assist, consent

Introduction

An expert is someone who has made every mistake in a very small field.

Niels Bohr

Watching a cerebral aneurysm being coiled may seem to the casual observer a procedure that is simple, low risk and low anxiety.

But coiling an aneurysm is analogous to walking along a 10 cm wide wooden plank which is easy when the plank is a foot above ground but terrifying when it joins two buildings 100 metres in the air.

Any slip by the neurointerventionist can be similarly disastrous and he should, therefore, be as fully prepared as possible for any eventuality prior to the procedure (table 2).

So he must have the best training, the best equipment and the best support from anaesthetics, technicians, nurses and even his administrators but most of all he should know all about the procedural complications of treating an aneurysm and how best to manage them.

Unfortunately although there is extensive literature on the incidence of complications there is a dearth of evidence on how best to treat them.

This article is a summary of how the author manages complications; there will be much that is by necessity anecdotal and much that other neurointerventionists will disagree with.

How Common Are Procedural Complications (table1)

In the most recently completed randomised controlled trail of coiling cerebral aneurysms (HELPS) the reported overall procedure related complication rate was 38% (191/499 patients). This rather frightening figure reduces to 22% when only clear cut procedure related complications are counted and only 7% of patients suffered any immediate neurological deterioration with an overall mortality of only 1.4%. So many complications can be successfully managed[1].

What are the Important Procedural Complications

Table 1 **Important Procedural complications**

Complication	Range	Comment
rupture	3 - 8.8%	Meta analysis 4.1%; Cloft[2] 8.8% if specifically looked for; Ross[3]
Thrombo-embolism	5-25%	If carefully looked for 28% with 5% symptomatic; Peltz[4] 8 % in HELPS[1]
Parent vessel occlusion	2-4%	2.4 % in HELPS[1]
"Coil migration"	5%	HELPS[1]

Preparing for an Interventional Case (table 2)

Time spent on reconnaissance is seldom wasted (my father).

Table 2 **The golden rules of neurointervention.**

Rule	Action	Comment
1	See the patient	Grading of patients is often incorrect-you must get a baseline GCS. If they have deteriorated consider another scan to check for - hydrocephalus, rebleed,vasospasm etc – Check for co-morbidities If Poor grade -consider a minimal approach?
2	See the Relatives	If 7% of your patients are likely to deteriorate due to your procedure. You MUST establish rapport with the relatives/partners if only by phone, or your life will become hell.
3	Analyse the CT	CT – which aneurysm has bled – Haematoma – Hydrocephalus CTA – dissection?/ neck size /thrombus CTP – ischaemia
4	Analyse the DSA	Access- aortic arch – do you need long sheath – Simmons shape guide Assist device- wide neck Multiple aneurysms– which to treat
5	Have coffee with your anaesthetist	– Make sure he doesn't drop the blood pressure with his drugs – Make sure he is prepared for rupture
6	Decide on anticoagulant And antiplatelet regime	– remember up to 20% of patients are resistant to aspirin / plavix – remember that heparin thrombocytopenia can occur
7	Prepare an assist device	– if the aneurysm is high risk e.g. small
8	Have ready	– Protamine/abciximab/iv aspirin – A snare with which you are familiar – a colleague you can talk to if all else fails
9	Equipment	Use equipment you are familiar with – if not have someone who is familiar with it
10	COMPLICATION	"Experience is not what happens to you, its what you do with what happens to you " (Aldous Huxley) YOU MUST LEARN FROM EACH COMPLICATION – but not immediately- too painful- BUT review your cases at least monthly

Thromboembolic Complications

Thromboembolic complications are the most common procedure related problem encountered during the coiling of aneurysms. In a retrospective review of 59 of patients Pelz [4] recorded a 28% incidence of thromboembolic events, 5% of patients having a permanent disability directly attributable to the event. These patients all had a bolus of heparin 3-5000 prior to intervention. Other studies have reported an incidence of between 4 and 6% thromboembolic events [3,5]. There is some confusion about the classification of these events. There is clot at the aneurysm neck arising from the coil ball; there is parent vessel occlusion and there is distal embolism all these events can be classified as "thromboembolic" but the distinctions are useful as management can be tailored to the individual situation.

The commonest event is the development of clot at the neck.

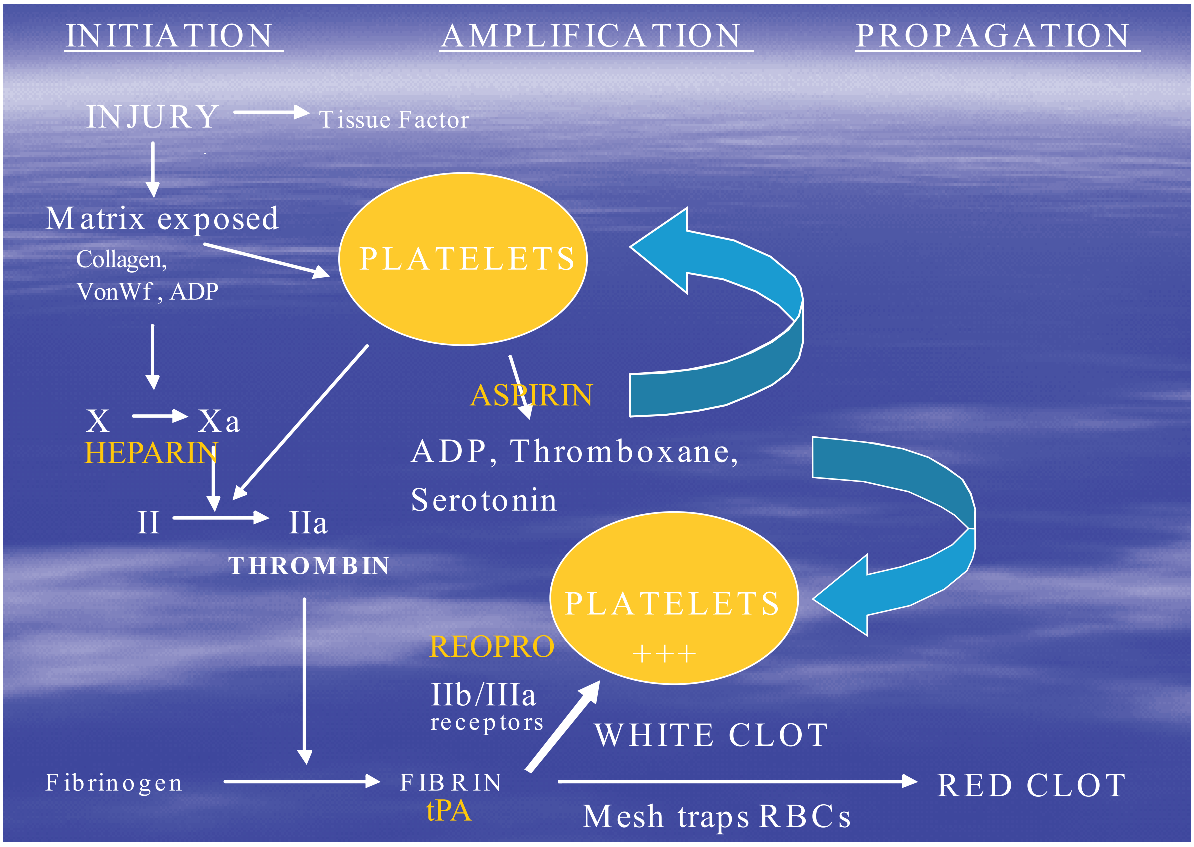

Figure 1 A schematic outline of the clotting pathway and its interaction with platelets.. The site of action of the main antiplatelet and thrombolytic agents (adapted from R Laitt).

Clot at The Aneurysm Neck

Clot at the aneurysm neck on the coil ball is the often the first sign of a significant thromboembolic complication (figure 2). The response should be measured and will depend on the anatomical circumstances. A proximal aneurysm neck e.g. at the origin of the posterior communicating artery without coil ball protrusion seldom progresses whereas clot at more distal

Table 3 **Illustrates the steps of a measured response to clot formation at the aneurysm neck**

1 early clot formation on proximal aneurysm without coil protrusion	Check heparinisation (ACT). Give bolus of Heparin 1-2000 units Remove any offending coil if not detached Give 1 mg IA Nimodopine proximal to clot Ask anaesthetist to increase BP by 20mm Hg if low
2 clot continues to progress in size or distal aneurysm with compropmise of parent artery.	Give IV aspirin 500 mg IV Make sure that the aneurysm fundus is packed
3 10 minutes clot progresses	IV Reopro or equivalent. Bolus dose e.g. ~10 mg
4 parent vessel occludes	Second bolus dose of Reopro
5 Fails to reopen after 5 minutes	Consider angioplasty with a compliant balloon for clot in M, A, distal ICA
6 Angioplasty fails	Consider clot retrieval device

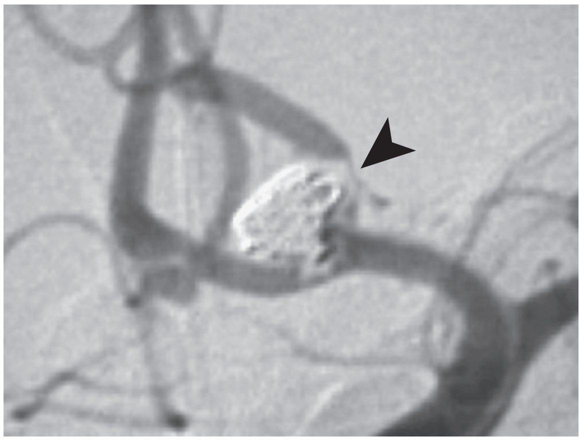

Figure 2 Clot forming on the coil ball (arrowhead).

sites such as the anterior communicating artery complex particularly with coil protrusion into a small parent artery often progresses rapidly to major artery occlusion.

Parent Vessel Occlusion

This may occur de novo or as a result of clot on the coil ball growing. De novo occlusion is usually secondary to catheter manipulation (figure 3). This may cause both damage to the intima stimulating clotting cascade and spasm of the vessel.

If occlusion occurs in the proximal internal carotid or vertebral artery dissection should be suspected and looked for as re-occlusion is likely to occur if the lesion is not stented (figure 4).

Treatment will depend on whether the aneurysm is protected or not. If an unprotected aneurysm bleeds due to intra arterial thrombolysis[6] or antiplatelet therapy the prognosis is poor.

If the aneurysm is not protected we would therefore not give antiplatelet drugs but give a further bolus of heparin to increase the ACT to at least 3 x control. With fresh clot retrieval devices are often relatively ineffective and we have found angioplasty with a compliant balloon such as a hyperglide balloon (EV3) surprisingly useful (figure 3 and 6). If these measures fail then we coil the aneurysm as quickly as possible and then give a Reopro bolus (for site of action see figure 1).

Distal Vessel Embolisation

This often turns out not to be as serious a complication as at first feared. Whilst checking that heparinisation is optimal (with an ACT of 3-4 being desirable in this situation) we perform biplanar angiography of all the major cerebral arteries that could provide collateral flow to the ischaemic territory. If the area involved is non eloquent and there is good collateral flow (figure 5) then powerful antiplatelet or thrombolytic drugs are not likely to be necessary. Increase the BP by 20 mm above baseline and wake the patient. If there is weakness then give a Reopro bolus, but this is seldom necessary.

If on the other hand there is poor collateral flow and the area supplied by the occluded branch is eloquent we would give REOPRO or consider a tPA bolus slowly IA through a microcatheter placed in the clot. tPA is almost completely metabolised by the liver in its first pass therefore rebleeding from a ruptured aneurysm is very unlikely if the tPA is infused distal to the aneurysm.

Coil Migration

Coil migration is a specific complication that may lead to thromboembolic sequelae. It is a loose term often used to cover a range of situations from simple bulging of coils through the aneurysm neck through the displacement of a coil tail and one or two loops of coil to distal embolism of a whole detached coil. The results of the HELPS trial and our own institutional results were presented at WIN 2008. In HELPS the incidence of coil migration was 6.6%-4.6%. The incidence of coil distal embolism was 3%.

The risk of distal coil embolism depends on;

- Shape, site of, and neck of aneurysm.
- Type of coil deployed.
- The use or lack of use of assist device.
- Poor coil detachment.

A wide necked small anterior communicating artery or a basilar trunk aneurysm are most likely sites to shed a coil. Complex coils are more likely to have resistance to embolisation than simple helical coils. Balloon assist devices may well prevent coil migration but also can cause it if the technique is not used with great care (S/B). Poor coil detachment site manufacture and technique in small aneurysms is the commonest cause of coil embolisation. The stiff coil detachment zone maybe 2 mm in length, so that when

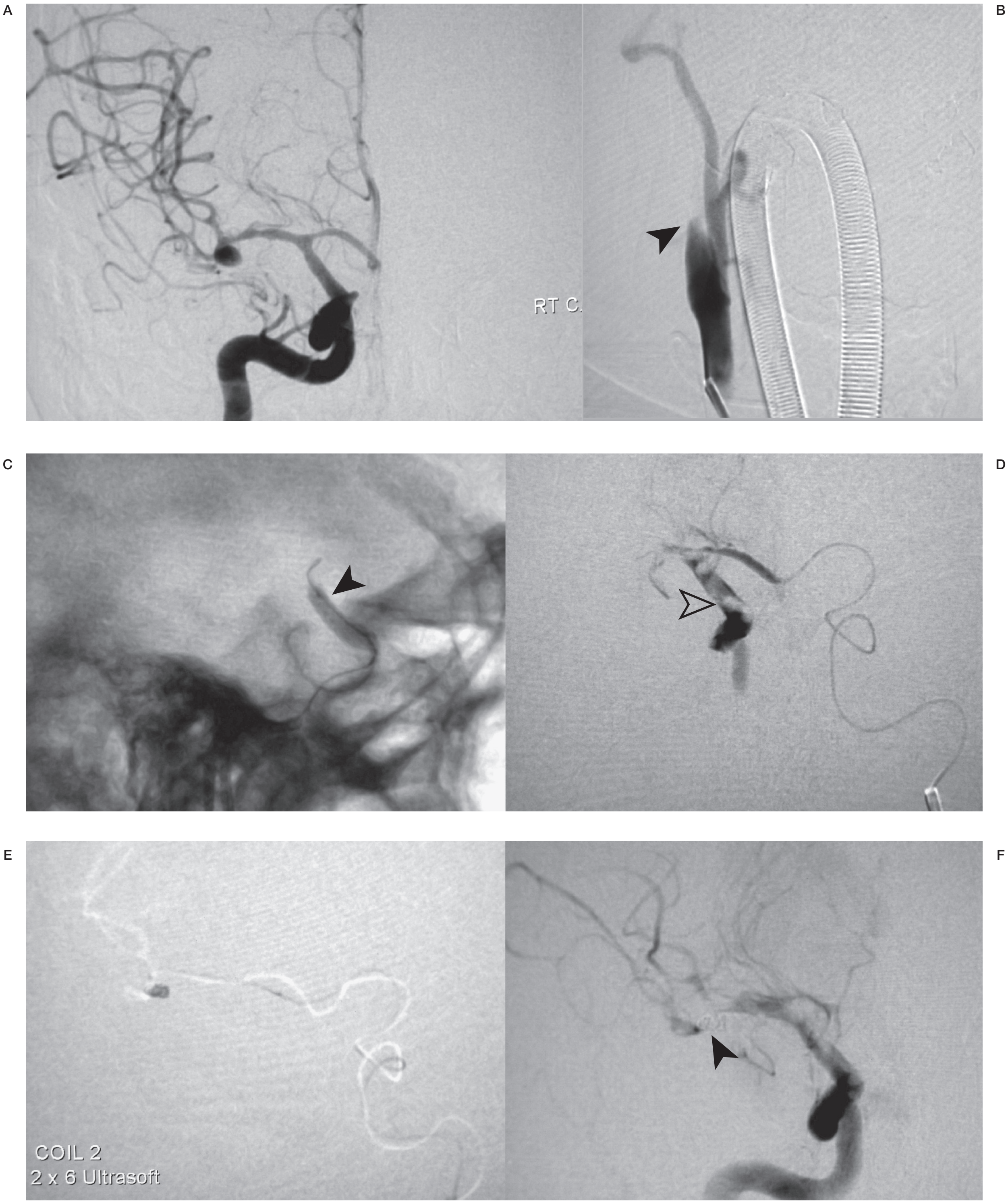

Figure 3 A) shows an MCA aneurysm with vasospam of MI. B) shows complete occlusion of the internal carotid (arrow); no evidence of dissection seen. C) balloon angioplasty arrow and clot retrieval failed in this case. D) catheterisation via the left carotid was performed and shows multiple thrombi (arrowhead) in the distal ICA and occlusion of the MCA. E) The aneurysm is being rapidly coiled from the left carotid approach. F) Reopro was then given with rapid recannalisation, note the residual spasm in the M1 (arrow) and clot in the distal ICA. Nimopodine 1 mg was given IA and good perfusion of the MCA was achieved. The patient had no clinical deficit after the procedure.

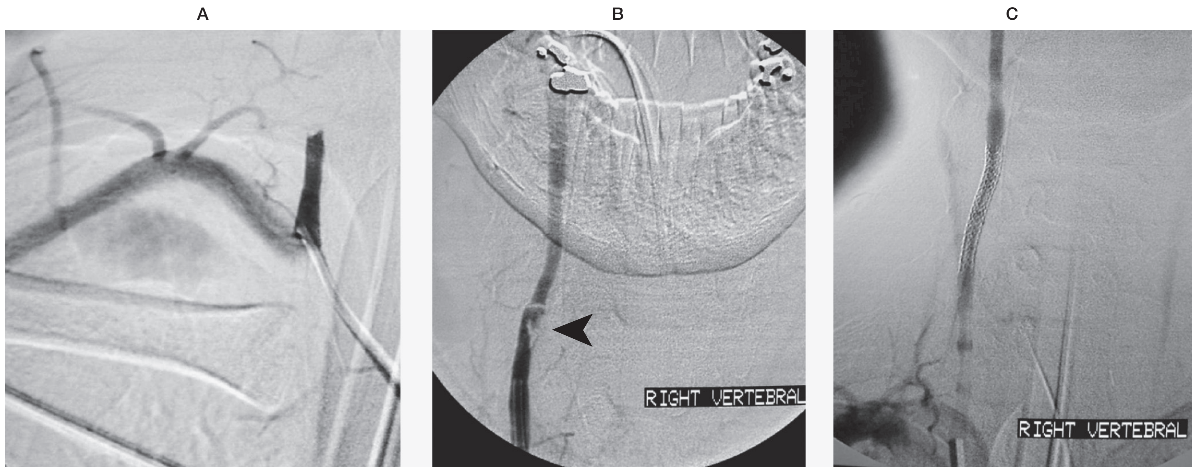

Figure 4 Proximal vertebral occlusion (A) secondary to dissection (arrow) (B) following thrombolysis this reoccluded and required stenting (C) distal embolus (arrow) in an MCA branch, see delayed collateral flow in the image below.

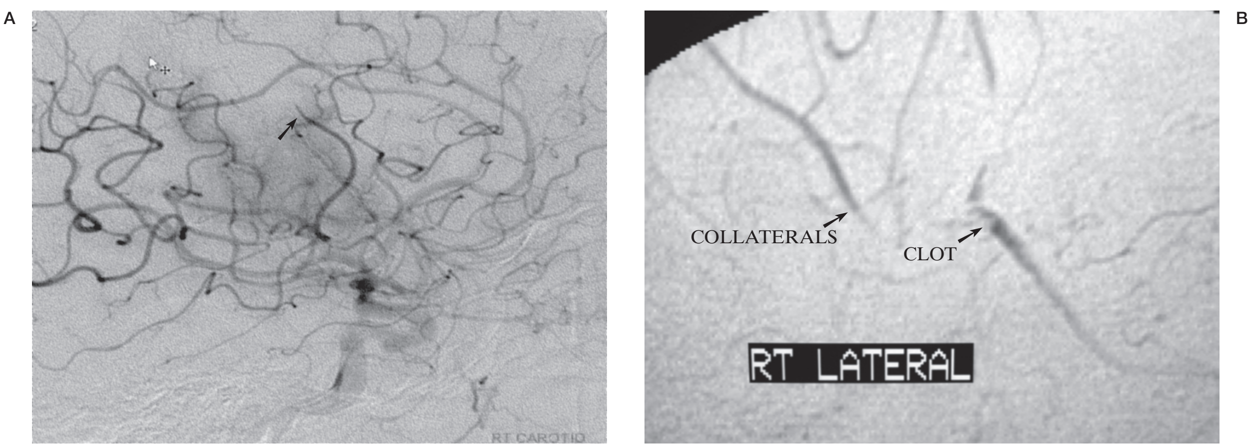

Figure 5 Distal embolus (arrow) in an MCA branch, good collateral flow to the affected region. This was managed with fluids and hypertension with no resultantclinical deficit.

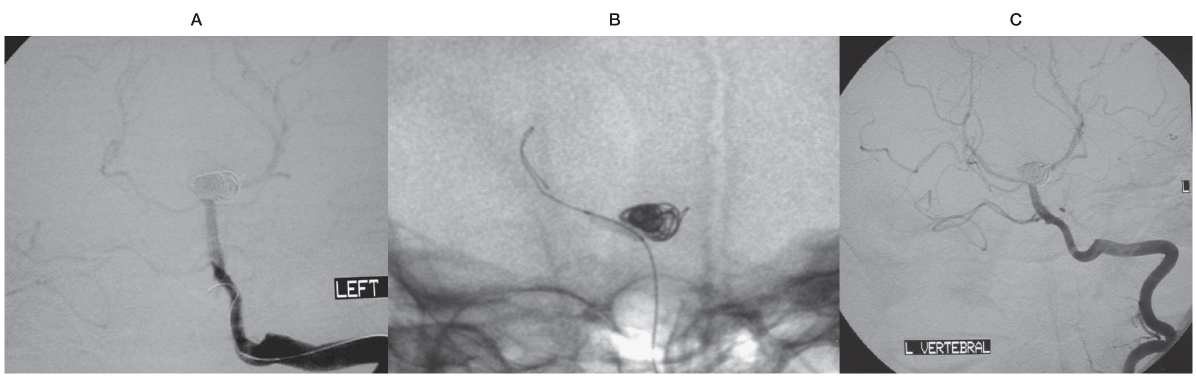

Figure 6 Loss of the right posterior cerebral artery (A), salvage angioplasty (B) coil ball remodelled (C) with artery reopened.

the aneurysm is small this stiff section of the coil is often re-engaged by the microcatheter after detachment so that as the catheter is retrieved it will frequently bring with it a loop or indeed the entire coil with it with potentially disastrous consequences. After detaching a small coil it is

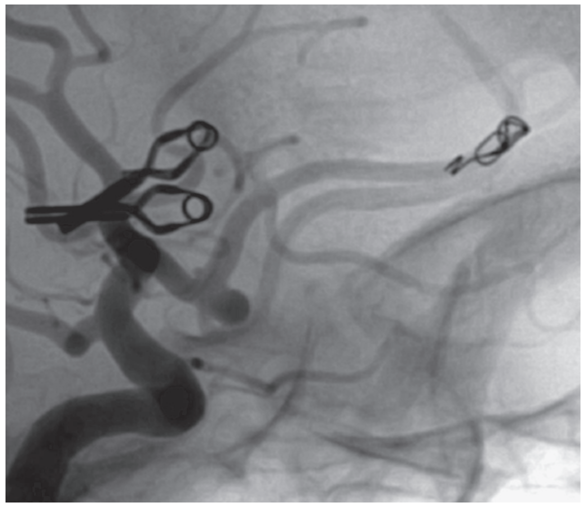

Figure 7 Distal coil embolisation (arrow). Distal coil embolisation; the coil is acting like a stent and not obstructing flow.

A B

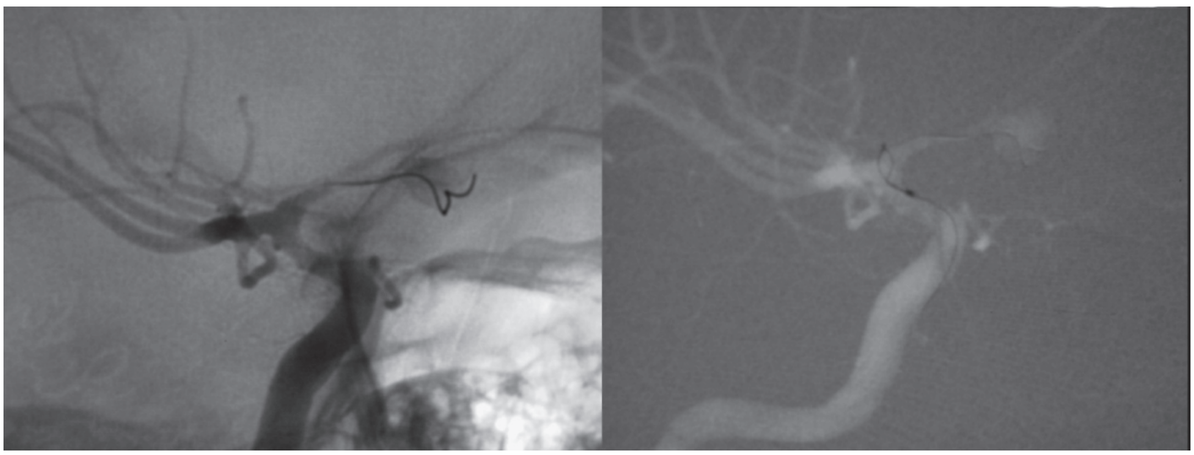

Figure 8 Coil migration (A) the long tail of coil can be stented to the artery wall or retrieved in this case by a goose necked snare (B),

A B

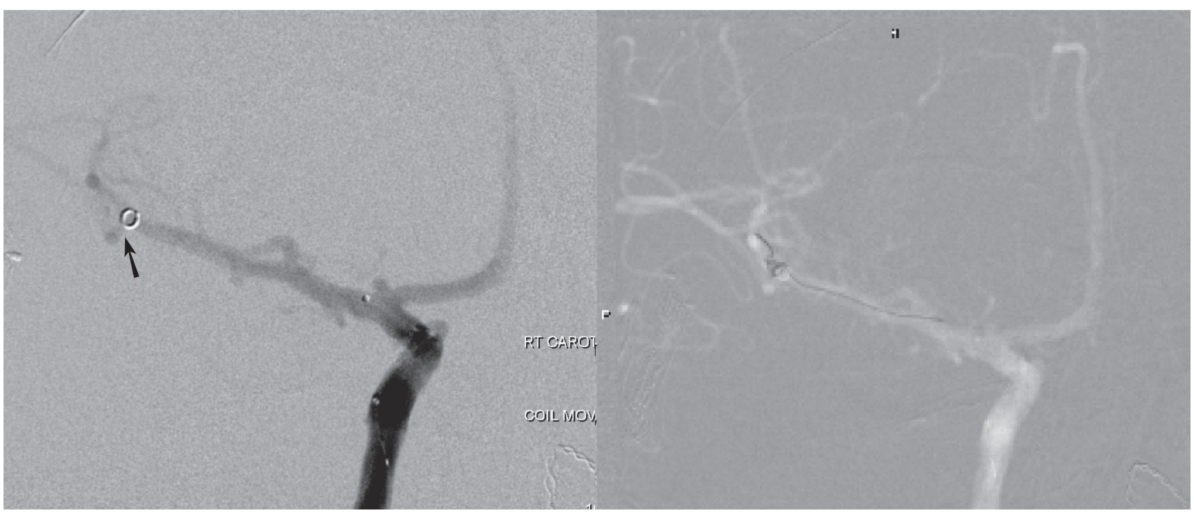

Figure 9 A small helical coil arrowhead (A) being retrieved by a Merci device (B).

recommended the coil pusher is retrieved only a few centimetres and then slowly re-introduced. This in itself is a gentle way to ease the catheter tip out of the aneurysm -if the catheter remains in the aneurysm the coil pusher should be advanced to the catheter tip to ease the tip of the coil out of the catheter. If a coil does migrate locally bulging through the neck balloon remodelling may well be successful in retrieving the situation and massage the offending coil back into the aneurysm (figure 6).

If a loop of coil or more comes out of the aneurysm and particularly if this loop is clearly being effected by pulsatile flow then the coil is likely to go onto distal embolisation. Here stenting can be a satisfactory solution with the coil being trapped between the stent and the vessel wall.

Finally how should distal embolisation be treated? This situation is analogous to distal clot embolisation. Frequently there is good collateral flow and the coil does not require to retrieved. Moreover small helical coils often deploy themselves in distal arteries like a doughnut or stent with little obstruction to flow (figure 7). If this is not the situation and an eloquent brain area is at risk the coil should be retrieved. This is often easier when the coil has a tail. There are a number of retrievers on the market. I have had greatest success with a goose necked snare (Amplatz or Boston Scientific) or a Merci device (Concentric) (figure 8, 9). A new microsnare fresh on the market is one that can be introduced down the microcatheter that has been used for coiling (Radius Medical USA). This looks promising particularly from the point of view of speed of its deployment.

Rupture

Aneurysmal rupture is the most feared complication of interventional neuroradiology (figure10). Although rates of rupture around 5% are typical, mortality in more recent reports due to rupture appears to be reducing with Van Rooij reporting a mortality of 0.7% and morbidity of 0.4% due to rupture [7].

Causes Of Aneurysm Rupture

There is an increase risk of rupture in small aneurysms and posterior circulation aneurysms [7]. The Southampton experience presented by Millar in 2006 was again that rupture was common in small aneurysms and aneurysms with a sharp angle between the parent vessel and fundus. The aneurysm can be perforated through the dome by a guide wire or micorcatheter. Tortuous proximal anatomy increases the friction of the microcatheter and when advanced it may do so in jumps. It is sensible therefore to approach an aneurysm with caution particularly if there are proximal carotid loops. If the aneurysm can be entered with the microwire sheathed inside the microcatheter this may reduces the risks of perforation. If both the microcatheter and the microwire have a distal curve they are less likely to impinge directly on the wall. Finally is the aneurysm is small and high risk I usually enter the aneurysm with a soft coil- the catheter will follow the loops of coil if it is gently advanced whilst slowly retrieving the coil. Coils themselves may cause rupture even if soft coils are used this is often the last coil and rupture may either occur at the neck or the dome.

Management of Rupture

Be prepared and stay calm. If primed the anaesthetist will have Protamine ready to reverse the Heparin. Deep anaesthesia with "burst suppression" will reduce the oxygen demands of the brain allowing it to survive hypo perfusion for longer. If the patient has a ventriculostomy this will mitigate against some of the effects of haemorrhage such as raised intracranial pressure and in some centres this is the rule even where the ventricles are only mildly dilated. If the patient has a endovascular compliant balloon in situ this should be inflated; across the neck of the aneurysm if it receives blood from two different directions, otherwise proximal to the leaking aneurysm. If the rupture is caused by a coil the traditional advice in this situation is to continue deploying coil loops. This, however, is not always the best advice as this may simply enlarge the hole by pushing a large loop through the dome wall. It may be better if you have good catheter tip control to bring the catheter back a few mm and then deploy further loops in the aneurysm. If there is little control of the catheter tip it may be best to leave the catheter in situ and disturb the situation as little as possible. A second micro-catheter can then be carefully introduced (the RHV will accommodate 2 micro-catheters but can result in the

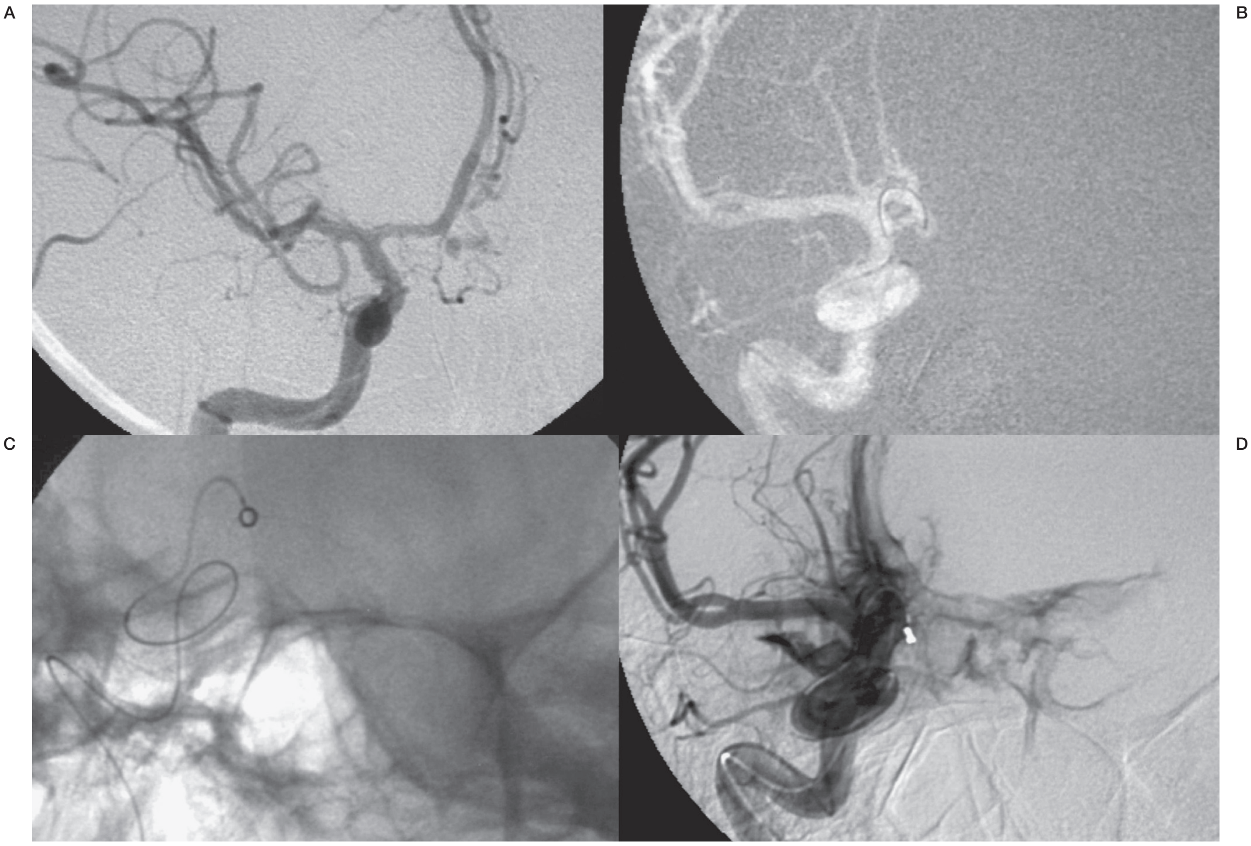

Figure 10 A small narrow necked aneurysm (A) in combination with the very tortuous proximal cerebral vessels (B) this is a high risk of rupture situation. The catheter tip is placed too close to the wall of the dome of the aneurysm. The coil and catheter in this situation often have stored energy (C) which over time releases into the aneurysm causing rupture (D)

second catheter inadvertently moving the first catheter distally) coils can then be placed within the aneurysm from the neck. If a micro-catheter has passed through the aneurysm wall then first try deploying a soft coil outside the aneurysm. Then either bring up a second micro-catheter and coil inside or do this by withdrawing the offending catheter

Small Aneurysms and Rupture

Several authors have recorded higher rates of rupture in small aneurysms (figure 10). Morris in his excellent textbook [8] lists three reasons for this, to paraphrase:

1. Small degree of leeway for manipulating the micro-wire and microcatheter: release of tension in the microcatheter on removing the microwire can result in the microcatheter leaping forward.
2. Mismatch of coil size and aneurysm size is much more important in small aneurysms. Deploying coils that are too large will lead a disproportionate increase in transmural pressure.
3. Small coils retain their shape memory to a far greater degree therefore in an irregular small aneurysm this generates greater surface tension or shear stress than in a large aneurysm.

Recently a fourth and fifth cause of rupture in these small aneurysms has been added; Lim et al have shown that the stiff part of the coil (the detachment zone) can protrude up to 1 mm proud of the microcatheter and that the distance to the detachment zone of the coil and the distal to tip marker maybe as great as 2.8 mm with a range of 1.2-2.8 mm [9]. Coiling of small aneurysms require a different technique to reduce the risk of rupture. A soft tip catheter such as the Prowler 10 (Cordis) will deflect easily. The catheter should not be placed close to the dome wall but close to the neck so that as pressure rises in the aneurysm the catheter can be deflected out of the aneurysm. Finally using a soft coil rather than a micro-wire may be the

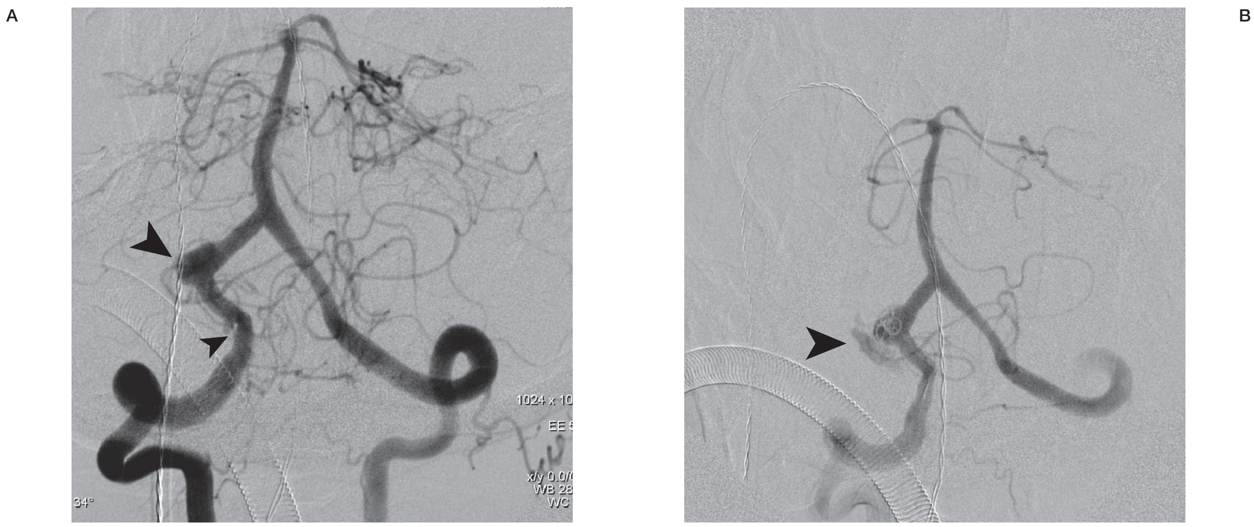

Figure 11 There is a dissected right vertebral artery with two distict aneurysms (arrows) (A). Stenting followed by coiling the aneurysm has resulted in rupture (arrow) (B) Normally this would have been treated by parent vessel occlusion but the left subclavian was completely occluded.

only way of entering through small necks as well as the safest.

Dissecting Aneurysms

Dissecting aneurysms is another fragile situation; the apparent aneurysm is often only the tip of the iceberg (figure 11A) and represents a false aneurysm segment of a much longer diseased segment. These should ideally be treated by parent vessel occlusion but if the patient is dependent on that vessel this is not an option. It may well be best simply to stent or double stent the vessel. If coiling is performed then this should be done with great caution, as rupture is common (figure 11B).

Deconstructive Techniques

Deconstructive techniques are commonly used for large internal carotid aneurysms frequently para-opthalmic in origin. Occlusion of the vessel +/- the aneurysm has two complications to avoid; stroke and visual loss. The risk of both can be reduced by properly performing a Balloon Occlusion Test (BTO). The cornerstone of a well performed BTO is clinical testing of the patient whilst the balloon is inflated. However several adjutant techniques increases the safety of the procedure (table 4). The value of multiple tests is illustrated by the case below (figure 12). Post operative management of patients who have carotid occlusion is critical. We nurse the patients flat monitoring the BP with an intra-arterial line for 48 hrs. Elderly patients frequently have a labile BP and any episodes of hypotension must be treated quickly during this 48 hr period.

Complications Due to Coil Types

Hydrocoil

These coils have become popular on account of the increased packing density achieved when they swell and probable reduced aneurysm recurrence rate. There are reports of increased risk of hydrocephalus and perianeurysmal inflammation. This has been reported in large para-ophthalmic aneurysms. Two patients have suffered a deterioration in visual acuity, one responding to steroids [12] this has also been reported with bare platinum. The HELPS trial comparing bare platinum with hydrocoil showed no significant difference in mortality/morbidity at 3 months.

Complications Due to Assist Devices

The overall complication rate of complications due to assist devices probably depends to a large extent on the experience of the in-

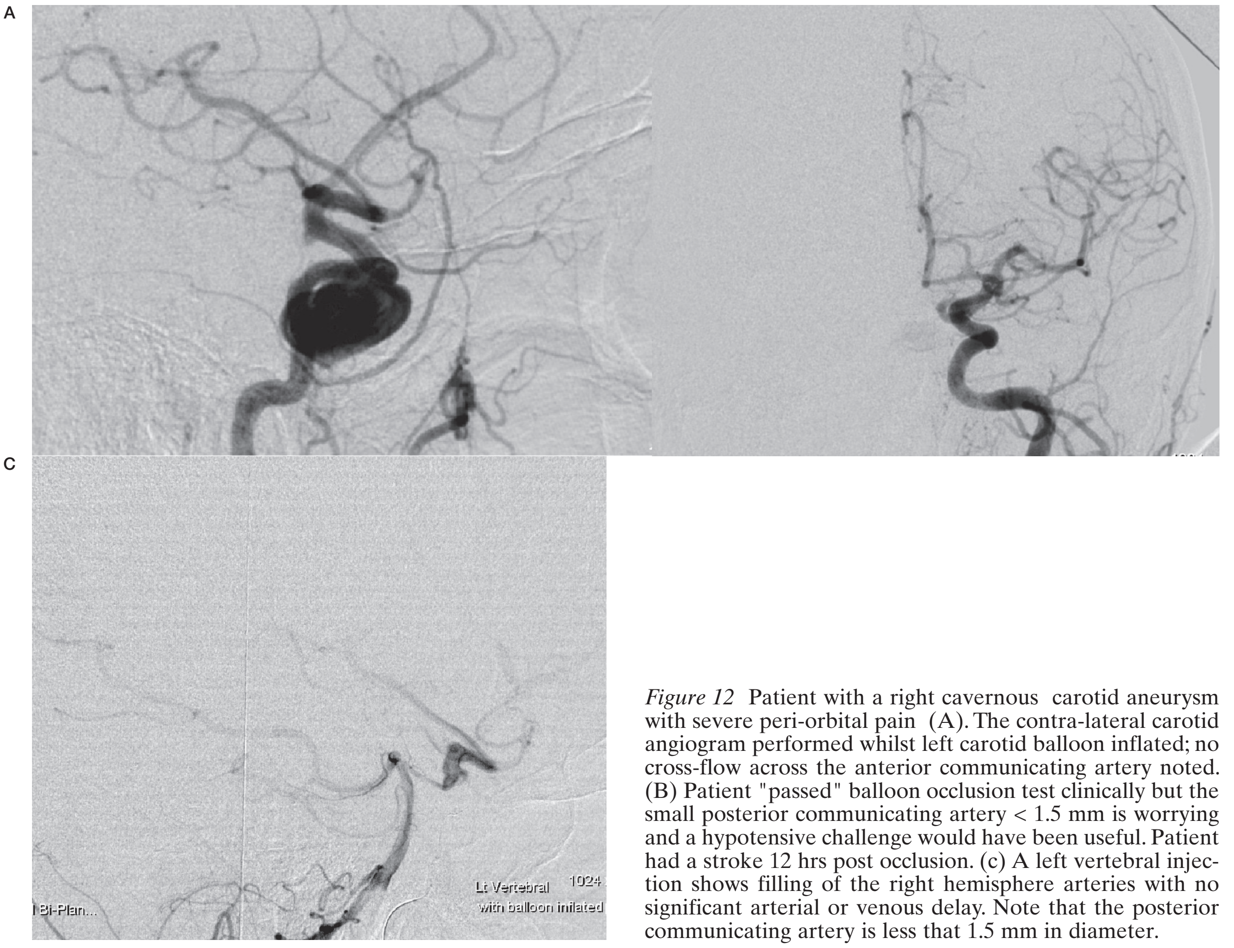

Figure 12 Patient with a right cavernous carotid aneurysm with severe peri-orbital pain (A). The contra-lateral carotid angiogram performed whilst left carotid balloon inflated; no cross-flow across the anterior communicating artery noted. (B) Patient "passed" balloon occlusion test clinically but the small posterior communicating artery < 1.5 mm is worrying and a hypotensive challenge would have been useful. Patient had a stroke 12 hrs post occlusion. (c) A left vertebral injection shows filling of the right hemisphere arteries with no significant arterial or venous delay. Note that the posterior communicating artery is less that 1.5 mm in diameter.

Table 4

TEST	**RESULT**
4 vessel cerebral angiography with balloon inflated.	Establishes good cross flow via the anterior and the posterior communicating arteries.
Comparison of the early venous phase with contralateral DSA perfomed with balloon inflated.	A delay of less than 2 seconds between the filling of the venous phase of the cerebral hemispheres indicates that carotid occlusion is safe [10].
SPECT	May illustrate hypoperfusion when clinically the patient shows no deficit.
Xenon CT	As above may detect hypoperfusion but involves moving the patient with balloon in situ- so not widely used in Europe.
Balloon occlusion across the ophthalmic artery.	A difficult manoeuvre with a short balloon as it tends to slip round the carotid bend. But is said to detect potential visual loss in the 10% at risk [11].
Hypotensive challenge aim to reduce BP for at least 20mm HG for 5minutes.	If the results of the other tests are in any way equivocal a hypotensive challenge is indicated.

terventionist. Several authors have found that the use of balloons carries an increased complication rate; Sluzeweski et al had a combined mortality and morbidity of 14.1% compared to conventional coil embolisation of 3% [13]. This paper was criticised on the grounds that the authors were using old relatively non compliant balloons and only performing on average 7 cases with balloon assist/year. However in the HELPS trail where centres were often using balloons in over 50% of cases again there was a higher proportion of complications when balloon assist was used. Likewise with stent assisted cases in HELPS there was 66% mortality when used in the setting of acute SAH (within 2 weeks of ictus).

The situation is clouded by balloons and stents being used in more difficult cases and stents being used acutely as a "bale out " procedure but what evidence there is suggests that if a case can be performed without an assist device it should be particularly in the acute situation. Why do balloons cause complications? Rupture of a vessel is rare with compliant balloons but rupture maybe caused by the microwire through the balloon, often the tip is not in the field of view and can impinge on the vessel wall at a bifurcation or sharp bend. If the aneurysm is wide necked, despite a satisfactory position of the coil ball being obtained with the balloon inflated and deflated, the coils can migrate due to the coil ball stability being upset by coil detachment or micro-catheter removal. Finally as the balloon is being deflated it may suddenly leap distally dislodging coils this can be prevented by removing any slack in the balloon catheter and tethering it with the RHV. The use of stents for cerebral aneurysms by the Barrow and Cleveland clinics were reviewed by Lavine and Meyers [14]. The main complications were stroke (5-10%) and secondary carotid stenosis in 6% of which 25 were symptomatic. The clarification of anti platelet regimes will almost certainly reduce the rate of complications. As resistance to either aspirin or Clopidrogel (Plavix) is seen in up to 20% of cases Patients who can tolerate both agents should be placed on both for 5 days prior to stenting. If the procedure is to be performed in the acute situation in stent thrombosis is common and IV aspirin and Plavix via the NG tube prior to stent deployment may be used.

References

1 White PM, Lewis SC, Nahser H et Al: Hydocoil Endovascular Aneurysm Occlusion and Packing study (HELPS trial): procedural safety and operator assessed Efficacy results. Am J Neuroradiol 29: 217-23, 2008.
2 Cloft H, Kalmes DF: Cerebral aneurysm perforations complicating therapy with Guglielmi detachable coils: a meta analysis 23: 1703-9, 2002.
3 Ross IB, Dhillon GS: Complications of endovascular treatment of cerebral aneurysms. Surg Neurol 64: 12-19, 2005.
4 Pelz DM, Lownie SP, Fox AJ: Thromboembolic events associate with the treatment of cerebral aneurysms with Guglielmi deachable coils. Am J Neuroradiol 19: 1541-7, 1998.
5 Henkes H, Fischer S, Weber W et Al: Endovascular coil occlusion of 1811 intracranial aneurysms early angiographic and clinical results. Neurosurgery 54: 268-80, 2004.
6 Cronquist M, Pierot L, Boulin A: Local thrombolysis of thromboemboli occuring during treatment of intracerebral aneurysms: a comparison between anatomic results and clinical out come. Am J Neuroradiol 19: 157-65, 1998.
7 Van Rooij WM, Sluzewski M, Beute GN et Al: Procedural complications of coiling ruptured intracranial aneurysms; incidence and risk factors in a consecutive series of 681 patients. Am J Neuroradiol 27: 1496-01, 2006.
8 Morris P: Practical Neuroangiography Lippincott Williams and Wilkins 2002: 79.
9 Lim YC, Lim BM, Shin YS et Al: Structural limitations of currently available microcatheters and coils for endovascular coiling of very small aneurysms. Neuroradiology 50: 423-9, 2008.
10 Abud DG, Spelle L, Mounmayer C et Al: Venous Phase Timing during Balloon test occlusion as a criterion for permanent Internal Carotid Artery Sacrifice. Am J Neuroradiol 26: 2602-9, 2005.
11 Shaibani A, Khawar S, Bendok B et Al: Temporary Balloon occlusion to assess the adequacy of collateral flow to the retina and tolerance for endovascular coiling. Am J Neuroradiol 25: 1384-1386, 2004
12 Pickett GE, Laitt RD, Herwadekar A et Al: Visual pathway compromise after hydrocoil treatment of large ophthalmic aneurysms. Neurosurgery 61: 873-4, 2007.
13 Sluzewski M, van Rooij WJ, Beute GN: Balloon assisted coil embolisation of intracranial aneurysms: incidence, complications and angiographic results. J Neurosurg 105: 396-9, 2006.
14 Lavine SD, Meyers PM: Application of new stenting techniques and technologies: stenting for cerebral aneurysm. Clinical Neurosurgery 54: 64-9, 2007.
15 White JB, Cloft HJ, Kalimas DF: But did you use HydroCoil? Perianeurysmal edema hydrocaphalus with bare pletinum cells. Am J Neuroradiol 29: 299-300, 2008.

R. Sellar, MD
65 Ravelston Dykes Rd
UK EH4 2XU Edinburgh, Scotland UK
E-mail: rsellar@staffmail.ed.ac.uk
rs@skull.dcn.ed.ac.uk